Topic 7.1
HW set 1

EQUILIBRIUM CONSTANT (K)

Name _____

Write the expression for the equilibrium constant K for the reactions below.

1. $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$

$$\frac{[NH_{3(g)}]^2}{[N_{2(g)}][H_{2(g)}]^3}$$

[products] / [reactants]

2. $2KClO_3(s) \leftrightarrow 2KCl(s) + 3O_2(g)$

all solids are 1 in K_c

$$\frac{[KCl_{(s)}]^2[O_{2(g)}]^3}{[KClO_{3(s)}]^2} \rightsquigarrow [O_{2(g)}]^3$$

3. $H_2O(l) \leftrightarrow H^+(aq) + OH^-(aq)$

all liquids are 1

$$\frac{[H^+_{(aq)}][OH^-_{(aq)}]}{[H_2O_{(l)}]} \rightsquigarrow [H^+][OH^-]$$

4. $2CO(g) + O_2(g) \leftrightarrow 2CO_2(g)$

$$\frac{[CO_2]^2}{[CO]^2[O_2]}$$

5. $Li_2CO_3(s) \rightarrow 2Li^+(aq) + CO_3^{-2}(aq)$

$$\frac{[Li^+]^2[CO_3^{2-}]}{[Li_2CO_3]} \rightsquigarrow [Li^+]^2[CO_3^{2-}]$$

1

CALCULATIONS USING THE EQUILIBRIUM CONSTANT

Name Key

Using the equilibrium constant expressions you determined on page 79, calculate the value of K when:

1. $[NH_3] = 0.0100\ M$, $[N_2] = 0.0200\ M$, $[H_2] = 0.0200\ M$

$$\frac{(0.01)^2}{(0.02)(0.02)^3} = 62500$$

favors products

2. $[O_2] = 0.0500\ M$

$$[0.05]^3 = 0.000125$$

favors reactants

3. $[H^+] = 1 \times 10^{-8}\ M$, $[OH^-] = 1 \times 10^{-6}\ M$

$$[1 \times 10^{-8}][1 \times 10^{-6}] = 1 \times 10^{-14}$$

favors reactants

4. $[CO] = 2.0\ M$, $[O_2] = 1.5\ M$, $[CO_2] = 3.0\ M$

$$\frac{[3]^2}{[2]^2[1.5]} = 1.5$$

slightly favors products

5. $[Li^+] = 0.2\ M$, $[CO_3^{-2}] = 0.1\ M$

$$[0.2]^2[0.1] = 0.004$$

favors reactants

Name:_____
Period:_____

7/17 Homework 1: Read p. 311-316 and complete exercises #1-6

Exercises

1 Which statements are correct for a reaction at equilibrium?

I The forward and reverse reactions both continue. ✓
II The rates of the forward and reverse reactions are equal. ✓
III The concentrations of reactants and products are equal. ✗

A

A I and II only **B** I and III only **C** II and III only **D** I, II, and III

2 Which statement is always true for a chemical reaction that has reached equilibrium at constant temperature?

C

A The yield of product(s) is greater than 50%. ✗
B The rate of the reverse reaction is lower than that of the forward reaction. ✗
C The amounts of reactants and products do not change.
D Both forward and reverse reactions have stopped. ✗

3 Which statement is *not* true for a mixture of ice and water at equilibrium at constant temperature?

B

A The rates of melting and freezing are equal. ✓
B The amounts of ice and water are equal.
C The same position of equilibrium can be reached by cooling water and by heating ice. ✓
D There is no observable change in the system. ✓

Exercises

4 Write the equilibrium constant expression for the following reactions:

(a) $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ a) $\frac{[NO_2]^2}{[NO]^2[O_2]}$

(b) $4NH_3(g) + 7O_2(g) \rightleftharpoons 4NO_2(g) + 6H_2O(g)$ b) $\frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7}$

(c) $CH_3Cl(aq) + OH^-(aq) \rightleftharpoons CH_3OH(aq) + Cl^-(aq)$ c) $\frac{[CH_3OH][Cl^-]}{[CH_3Cl][OH^-]}$

5 Write the equations for the reactions represented by the following equilibrium constant expressions

(a) $K_c = \frac{[NO_2]^2}{[N_2O_4]}$ a) $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

(b) $K_c = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$ b) $CH_{4(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3H_{2(g)}$

We are working w/ homogeneous reactions

6 Write the equilibrium constant expressions for the following chemical reactions:

(a) fluorine gas and chlorine gas combine to form $ClF_3(g)$
(b) NO dissociates into its elements
(c) methane, CH_4, and steam react to form carbon monoxide and hydrogen

a) $\frac{[ClF_3]^2}{[F_2]^3[Cl_2]}$ $3F_2 + Cl_2 \rightleftharpoons 2ClF_3$

b) $\frac{[N_2][O_2]}{[NO]^2}$ $2NO_{(g)} \rightleftharpoons N_{2(g)} + O_{2(g)}$

c) $\frac{[CO][H_2]^3}{[CH_4][H_2O]}$ $CH_{4(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3H_{2(g)}$

Name:_____
Period:_____

7/17 Homework 2: Read p. 317-326 and complete exercises #7-15

Exercises

7 When the following reactions reach equilibrium, does the equilibrium mixture contain mostly reactants or mostly products at the specified temperature? Assume that the value for K_c given corresponds to the temperature of the reaction mixture.

(a) $N_2(g) + 2H_2(g) \rightleftharpoons N_2H_4(g)$ $K_c = 7.4 \times 10^{-26}$ very small — favors reactants

(b) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ $K_c = 2.7 \times 10^{-18}$ very small - favors reactants

(c) $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $K_c = 6.0 \times 10^{13}$ very large - favors products

8 The equilibrium constant for the reaction:

$$H_2O(g) + Cl_2O(g) \rightleftharpoons 2HOCl(g)$$

$$K_c = \frac{[HOCl]^2}{[H_2O][Cl_2O]}$$

is 0.0900 at 298 K.

Determine whether the following sets of conditions represent an equilibrium mixture for the reaction at this temperature. For those not at equilibrium, determine in which direction the reaction will proceed.

	$[H_2O]$	$[Cl_2O]$	$[HOCl]$
(a)	0.100	0.100	1.00
(b)	0.49	0.040	0.042
(c)	0.19	0.00033	0.083

a) $\frac{[1]^2}{[0.1][0.1]} = 100$ proceeds to the left

b) $\frac{[0.042]^2}{[0.04][0.49]} = 0.09$ at equilibrium

c) $\frac{[0.083]^2}{[0.00033][0.19]} = 109$ proceeds to left

9 At a given temperature, the reaction

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

has a value of $K_c = 278$. Determine values of K_c for the following reactions at this temperature.

(a) $4SO_2(g) + 2O_2(g) \rightleftharpoons 4SO_3(g)$

(b) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$

(c) $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$

a) $K_c^2 = (278)^2 = 77,284$

b) $\frac{1}{K_c} = (278)^{-1} = 0.0034$

c) $\frac{1}{\sqrt{K_c}} = \sqrt{(278)^{-1}} = 0.06$

HW set 2

LE CHATELIER'S PRINCIPLE

Name _____

Le Chatelier's Principle states that when a system at equilibrium is subjected to a stress, the system will shift its equilibrium point in order to relieve the stress.

Complete the following chart by writing left, right or none for equilibrium shift, and decreases, increases or remains the same for the concentrations of reactants and products, and for the value of K.

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 22.0\ kcal$$

$$\frac{[NH_3]^2}{[H_2]^3[N_2]}$$

Stress	Equilibrium Shift	$[N_2]$	$[H_2]$	$[NH_3]$	K
1. Add N_2	right	—	decreases	increases	remains the same
2. Add H_2	right	decreases	—	increases	"
3. Add NH_3	left	↑	↑	—	"
4. Remove N_2	left	—	↑	↓	"
5. Remove H_2	left	↑	—	↓	"
6. Remove NH_3	right	↓	↓	—	"
7. Increase Temperature	left	↑	↑	↓	changes
8. Decrease Temperature	right	↓	↓	↑	change
9. Increase Pressure	right	↓	↓	↑	no
10. Decrease Pressure	left	↑	↑	↓	no

5

LE CHATELIER'S PRINCIPLE CONTINUED

Name _____

$12.6\ kcal + H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

Stress	Equilibrium Shift	$[H_2]$	$[I_2]$	$[HI]$	K
1. Add H_2	right	—	decreases	increases	remains the same
2. Add I_2	R	↓	—	↑	
3. Add HI	left	↑	↑	—	
4. Remove H_2	left	—	↑	↓	
5. Remove I_2	left	↑	—	↓	
6. Remove HI	right	↓	↓	—	
7. Increase Temperature	right	↓	↓	↑	↑
8. Decrease Temperature	left	↑	↑	↓	↓
9. Increase Pressure	NONE				
10. Decrease Pressure	NONE				

$NaOH(s) \leftrightarrow Na^+(aq) + OH^-(aq) + 10.6\ kcal$

(Remember that pure solids and liquids do not affect equilibrium values.)

Stress	Equilibrium Shift	Amount NaOH(s)	$[Na^+]$	$[OH^-]$	K
1. Add NaOH(s)		—			
2. Add NaCl (Adds Na^+)	left	↑	—	↓	
3. Add KOH (Adds OH^-)	left	↑	↓	—	
4. Add H^+ (Removes OH^-)	right	↓	↑	—	
5. Increase Temperature	left	↑	↓	↓	↓
6. Decrease Temperature	right	↓	↑	↑	↑
7. Increase Pressure	none				
8. Decrease Pressure					

Name:_____
Period:_____

HW set 2

Exercises

10 The manufacture of sulfur trioxide can be represented by the equation below:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^\ominus = -197 \text{ kJ mol}^{-1}$$

What happens when a catalyst is added to an equilibrium mixture from this reaction?

B

A The rate of the forward reaction increases and that of the reverse reaction decreases. ✗
B The rates of both forward and reverse reactions increase. ✓
C The value of $\Delta H^\ominus$ increases. ✗
D The yield of sulfur trioxide increases. ✗

11 What will happen to the position of equilibrium and the value of the equilibrium constant when the temperature is increased in the following reaction?

14 + $Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad \Delta H^\ominus = +14$ kJ

$$K_c = \frac{[BrCl]^2}{[Br_2][Cl_2]}$$

	Position of equilibrium	Value of equilibrium constant
~~A~~	shifts towards the reactants	decreases
~~B~~	shifts towards the reactants	increases
C	shifts towards the products	decreases
(D)	shifts towards the products	increases

D

12 Which changes will shift the position of equilibrium to the right in the following reaction?

$$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$$

I adding a catalyst ✗
II decreasing the oxygen concentration ✓
III increasing the volume of the container ✓

A I and II only **B** I and III only **(C)** II and III only **D** I, II, and III

C

13 For each of the following reactions, predict in which direction the equilibrium will shift in response to an increase in pressure:

(a) $2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$ left - reactants
(b) $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ right
(c) $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ no shift

(14) How will the equilibrium:

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g) \qquad \Delta H = +ve$$

respond to the following changes?

(a) addition of $H_2(g)$
(b) addition of $CH_4(g)$
(c) a decrease in the volume of the container
(d) removal of $CS_2(g)$
(e) increase in temperature

a) left
b) right
c) left
d) right
e) right (endothermic)

Name:_____
Period:_____

15 The reaction

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \qquad \Delta H = -566 \text{ kJ mol}^{-1}$$

takes place in catalytic converters in cars. If this reaction is at equilibrium, will the amount of CO increase, decrease, or stay the same when:

(a) the pressure is increased by decreasing the volume?
(b) the pressure is increased by adding $O_2(g)$?
(c) the temperature is increased?
(d) a platinum catalyst is added?

a) decrease b) decrease
c) increase (exo - shifts left)
d) no change

7/17 Homework 3: Read p. 327-329 and complete exercises #16-18

Exercises

16 In the Haber process for the synthesis of ammonia, what effects does the catalyst have?

C

	Rate of formation of $NH_3(g)$	Amount of $NH_3(g)$ formed
A	increases	increases
B	increases	decreases
C	increases	no change
D	no change	increases

17 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^\ominus = -200 \text{ kJ}$

According to the above information, what temperature and pressure conditions produce the greatest amount of SO_3?

B

	Temperature	Pressure
A	low	low
B	low	high
C	high	high
D	high	low

18 Predict how you would expect the value for K_c for the Haber process to change as the temperature is increased. Explain the significance of this in terms of the reaction yield.

$N_2 + H_2 \rightleftharpoons NH_3 \quad -\Delta H$

shift to reactants as ↑temp
Kc decreases
So less NH_3 produced

8